Effect of moisture enhancement on sensory attributes, tenderness, and retail color of beef steaks from the *gluteus medius*

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Abstract

Retail color, palatability, and tenderness were evaluated on fresh moisture enhanced beef steaks removed from *gluteus medius* roasts. Roasts from USDA low Choice (n = 40) and low Select (n = 39) carcasses were divided in half by removing one control (**CON**) steak from the center to determine initial shear force. Each half received one of two treatments: 1) Brine injection (**BI**) pumped to 110% green weight (2.5% sodium lactate, 0.35% sodium tripolyphosphate and 0.65% sodium chloride); or 2) needle tenderized (**NT**). Steaks (2.54 cm) were removed from BI and NT roasts for Warner-Bratzler shear-force (aged 7, 14, and 21 d) and for sensory analysis (aged 14 d). Subjective (5 d; 5-member panel) and objective color (8 d; L*, a* and b*) were measured on steaks under retail display lighting. Overall, BI steaks (2.85 kg) were more tender ($P < 0.0001$) than NT steaks (3.47 kg) and CON steaks (3.51 kg), NT and CON steaks did not differ. Drip and cooking loss were less ($P < 0.0001$) in BI than NT steaks suggesting improved water retention. Sensory evaluation revealed that BI steaks had more ($P < 0.0001$) initial tenderness and juiciness, sustained tenderness and juiciness, beef flavor and overall greater preference than NT steaks. Objective color readings indicated that BI steaks were initially (d 1) darker (L*), less red (a*) and less yellow (b*) ($P < 0.0001$) than NT steaks. However, the change between d 1 and 8 readings were greater ($P < 0.0001$) for L* and b* in NT versus BI steaks suggesting that retail color was more stable in moisture enhanced steaks. Subjective color panel data reported no differences ($P > 0.05$) due to treatment, implying that L* and b* differences measured in objective evaluation may not be visible to the consumer. These results indicate that moisture enhancement may improve sensory attributes, tenderness and water retention, while stabilizing color in the retail case.

Keywords: Beef, Moisture Enhancement, Palatability

Introduction

Consistency in tenderness and palatability characteristics has recently become a concern in the beef industry. The majority of a beef carcass consists of lower quality cuts, which are declining in value as opposed to loin cuts (Cattle Fax, 1998). The *gluteus medius*, along with several other cuts from the round, are among these lower quality beef cuts with a relatively lower rank in WBSF values (J. B. Belew et al., 2003). McGee et al. (2003) reported that untreated control steaks from underutilized cuts from the inside round were tougher with higher WBSF than moisture enhanced (with a brine solution) steaks from like muscles. The National Beef Quality Audit (2000) reported that there has been an increase in beef carcasses grading select and low choice. These grades imply that there has been a decrease in intramuscular fat in the steaks, which has been correlated with juiciness and flavor. These characteristics in palatability, juiciness, tenderness, and flavor, are all important in selection of beef products by consumers.

Variations in cooking times and heat application are factors that affect the tenderness in beef products. In one survey, 58% of beef consumers cooked their beef products to “medium well” or “well done” (Yankelovich Partners, 1994). With a leaner meat, cooking times and temperatures should be monitored more attentively for a more desirable result. D. M. Wulf et. al, (1996) reported that $CaCl_2$ injection lessened the toughening effects of heating.

Consumers are not only concerned about tenderness of beef products, but also how they look in the retail case. Many consumers believe that freshness is correlated with meat color. Some studies concerning retail color have reported that the combined addition of NaCl and STTP improved the color of meat (Carpenter, 1961; Krause et al., 1978). Moisture enhancement is already used in the pork and poultry industry and has proved to be a commercial success (Ellenger, 1972).

In this study, beef steaks from select and low choice grades are injected with a brine solution three days post mortem. To determine the effects of the brine injection on important palatability traits of consumers, the steaks will be evaluated by proximate analysis, Warner-Bratzler Shear Force, cooking loss, drip loss, retail color (subjective and objective), and sensory attributes (initial tenderness, sustained tenderness, initial juiciness, sustained juiciness, beef flavor, and overall acceptability).

Objectives

To investigate the effects of high pressure moisture enhancement, grade (select or choice) and initial tenderness (tender or tough) from top sirloin (*gluteus medius*) roasts on: proximate composition, retail color, palatability, ultimate tenderness and shelf life.

Materials and Methods

Samples

Three steaks were removed from the center of 80 *gluteus medius* roasts (40 choice and 40 select) to determine initial tenderness (tough versus tender) and to serve as negative control (NC) steaks in shear force and cooking loss analysis. The remaining halves of the roasts were then given one of two treatments using a high pressure multi-needle injector (Model MI-300, Belham, Uden, Netherlands): 1) brine injection (BI) with a brine solution consisting of 2.5% sodium lactate, 0.35% sodium tripolyphosphate and 0.65% sodium chloride at 110% of green weight or 2) needle tenderized (NT) where injection occurred, but no brine solution was administered, serving as a positive control. After treatment, the roasts were cut into 2.54 cm steaks to evaluate tenderness (on d 7, 14, and 21), sensory attributes and cooking loss. Two samples were also removed from each roast to determine drip loss and chemical composition by proximate analysis.

Proximate Composition

The pH readings of each roast were taken post treatment and before steaks were separated for further analysis using a pH STAR (pH-star; SFK Inc., Denmark) meter and a Mettler-Toledo glass spear meat probe (Mettler-Toledo, Columbus, Ohio). To determine drip loss, samples were initially weighed then suspended on fish hooks inside a pre-weighed bag. After 7 and 14 d of storage at 4° C, the bags containing the purge lost from the samples were weighed again. Drip los was calculated using the formula: ([bag weight after aging – initial bag weight]/initial sample weight*100)

Samples for evaluating chemical composition were weighed before and after they were lyophilized to determine percent moisture. Afterwards, the samples were ground to a homogenous consistency using a coffee grinder and sent to Barrow Agee Lab in Memphis, TN for proximate analysis of percent fat, protein and ash (AOAC, 1990).

Tenderness and Cooking Loss

Initial tenderness was determined using one of the three steaks removed from the center of each roast. The roasts were labeled as either tough or tender depending on initial Warner-Bratzler shear force values taken on d 3 post mortem using a Texture Analyzer (TAX Texture Analyzer, Texture Technologies Corp., Scarsdale, NY), equipped with a WBS attachment. Tough steaks were those that had the highest WBSF values, while the tender steaks were those that had the lowest WBSF values.

Warner-Bratzler shear force measurements were taken after 7, 14, and 21 d of storage for each treatment group. Each steak was thawed at 4° C for 24 h prior to cooking. They were then cooked using an impingement oven (Lincoln Impinger, Food Service Products Inc., Fort Wayne, IN) at 176° C for approximately 11 min. to an internal temperature of 66° C and cooled for 4 h. Weight was measure for each steak prior to and after cooking to measure percent cooking loss, which was calculated with the formula: ([raw weight-cooked weight]/raw weight)*100. After the steaks were cooled, six 1.27 cm cores were removed, parallel to the muscle fibers, from each sample. The six cores were then shorn perpendicular to the longitudinal axis of the muscle fibers and values attained were averaged for each sample. All analysis was conducted according to AMSA (2001).

Sensory Attributes

Brine injected and needle tenderized steaks were randomly selected from the tough and tender treatment groups then thawed and cooked similarly to the steaks cooked for analysis of tenderness (WBS) and cooking loss. The samples were cut into 1 x 1 x 2.54 cm samples (trim and connective tissue removed) and served warm to a trained 6-member sensory panel (AMSA, 2001). Panelists rated each sample on a 10 cm (0 = extremely tough, dry, bland, and no-off-flavor: 10 = extremely tender, juicy, intense beef flavor, and pronounced off-flavor) unstructured line for initial tenderness, sustained tenderness, initial juiciness, sustained juiciness, beef flavor and overall acceptability. Also, panelists were asked to leave comments for each attribute if they felt the need. Data was collected using Compusense(r) five version 4.6 data collection and analysis software (Compusense Inc., Guelph, Ont., Canada).

Retail Color

The remaining steaks left from the roasts were vacuum-packed and stored in refrigeration (0 – 4^{o}C) away from light for 10 days. After storage, the steaks were removed from the packing and placed on a diaper pad in a Styrofoam tray (Genpak, Glen Falls, New York). A fresh cut surface was made on each steak and was allowed to bloom for approximately 30 minutes before samples were wrapped with an oxygen permeable film (0.0152 mm polyvinvyl chloride film with an oxygen transmission rate of 904.5 cm^3/24 h, at 21^{o}C; Koch Supplies, Kansas City Missouri) and placed in refrigeration (0-4^{o}C). The steaks remained under fluorescent lighting with the surface of the meat constantly exposed to 1049 lux of light during a 10-day period. A Minolta Chroma meter (Model = CR-300, Minolta Co., Ltd. Osaka, Japan), with a 50-mm diameter measurement area and a D65 illuminant, was used to evaluate retail color objectively by measuring L* (brightness), a* (red-green spectrum) and b* (yellow-blue spectrum) values once a day for the length of exposure time.

The subjective color was measured on steaks once a day for 5 days of storage in the same conditions as steaks for the objective color evaluation. A trained 5-member panel was used for investigation of subjective retail color and were asked to rate the steaks on an 8 point hedonic scale (1 = extremely unacceptable to 8 = extremely acceptable) once a day for the 5 days exposure period.

Statistical Analysis

Data were analyzed using MIXED and CORR procedures of SAS (1999, 1990). Changes in WBS, Objective Color, Subjective Color, Sensory Attributes and Chemical Composition over time (day) or panelist were analyzed as repeated measures including the effect of roast, moisture enhancement, grade, initial shear force, time or panelist, and associated interactions. Significance was based on a p-value less than 0.05.

Results

Proximate Composition and Drip Loss

Brine injected steaks had higher ($P < 0.05$) pH values and percent ash content than needle tenderized steaks while percent drip loss, moisture, fat and protein were significantly lower ($P < 0.05$) for brine injected steaks compared to needle tenderized steaks. The higher percentage of ash and higher pH paired with a decreased percentage of drip loss signifies that injection of the brine solution was successful. Also, ultimate pH has been reported to have an effect on drip loss, in that higher pH values cause myofibrillar repulsion and a decreased drip loss (Elliot, 1968).

A difference ($P < 0.05$) of 1.72% was exhibited by needle tenderized steaks with an increase in percent moisture when compared to brine injected steaks. Baublits et al. (2005)

reported increased water retention in all salt and salt/phosphate treatments. As the pH approaches the isoelectric point there is a decreased net protein charge thereby decreasing water binding (Weibicki et al., 1963).

Lastly, there was a significant difference in grade with select steaks having higher ($P < 0.05$) percent protein and lower ($P < 0.05$) percent fat, serving as evidence that the USDA grading system was accurate (Table 1).

Tenderness and Cooking Loss

Initial tenderness had no effect on the results throughout the aging process. Baublits et al. (2005) has shown that water retention increases upon addition of salt and phosphate, however in another study enhancement had no effect on cook loss in either steaks or roasts (Robbins et al., 2003). Cooking loss was significant in that brine injected steaks had lower ($P < 0.05$) percentages than needle tenderized steaks with a 17.1% difference between treatments (Table 1).

Both needle tenderized and negative control steaks had higher ($P < 0.05$) WBS values while a dramatic decrease ($P < 0.05$) is seen in brine injected steaks post treatment (Figure 2, Table 2). This suggests that the increase in tenderness is due to the brine solution and not to the needle injection. Overall, brine injected steaks (2.85 kg) were more tender ($P < 0.0001$) than needle tenderized steaks (3.47 kg) and control steaks (3.51 kg), needle tenderized and control steaks did not differ (Figure 1). Vote et al. (2000) also reported a decrease in WBSF values for *longissimus* steaks treated with various concentrations of a NaL, NaCl and STTP compared to un-treated steaks. Another study reported that untreated control steaks from underutilized cuts from the inside round were tougher with higher WBSF values than moisture enhanced (with a brine solution) steaks from like muscles (McGee et al., 2003). Additionally, Zheng et al. (2000)

reported decreased WBSF values due to the addition of STTP in poultry breast compared to untreated samples.

Sensory Attributes

Brine injected steaks had higher ($P < 0.05$) values in all sensory attributes (initial tenderness, sustained tenderness, initial juiciness, sustained juiciness, overall beef flavor, and overall acceptability) than needle tenderized steaks (Table 3). These results are supported by other studies which have shown that the addition of salts and phosphates increase sensory juiciness ratings (Miller and Harrison, 1965; McGee et al., 2003; Baublits et al., 2005). Other studies have also shown phosphate/salt based solutions used to enhance beef and pork resulted in improved flavor or unaffected flavor (Smith et al., 1984; Scanga et al., 2000; McGee et al., 2003).

Comments from the panelists revealed that over 75% of brine injected steaks were slightly salty however the brine injected steaks still had higher ($P < 0.05$) values for overall acceptability and beef flavor than needle tenderized steaks. These results contradict other studies where saltiness was perceived as undesirable and treated steaks were ranked lower in beef flavor intensity (Lawrence et. al., 2003). Initial tenderness and grade has no significant interactions with any of the attributes.

Retail Color

As expected, there was a significant decrease ($P < 0.05$) in L*, a* and b* readings, regardless of treatment as days progressed in retail display settings. Color measurements also report lower ($P < 0.05$) L*, a* and b* values for brine injected steaks compared to needle tenderized steaks. The rate at which the values decrease over the 8 d storage period is slower for brine injected steaks than needle tenderized steaks, suggesting that treated steaks may sustain color better than untreated steaks in the retail case (Figures 3-5, Table 4). Jensen et al. (2003) reported darker colors in chops pumped with 2% NaL as opposed to control or treatment chops without the addition of NaL. In the current study there was only one treatment with brine injection, therefore all brine injected steaks included an addition of NaL resulting in darker L* values. Banks et al. (1998) reported that no difference in L* values were reported due to the addition of 1 to 2% NaL. In the current report NaL was added at a 2.5% level. Murphy and Zerby (2004) reported lowered b* values in samples containing an addition of NaCl alone when compared to control samples at all times. Further, a* values have been shown to decrease (less red color) in enhanced beef round steaks due to the addition of salt and phosphate (Robbins et al., 2003). Finally, enhancement has been shown to be detrimental to retail display and color stability resulting in darker steaks and discoloration (Dhanda et al., 2001; Robbins et al., 2002).

During subjective color analysis, a significant decrease in color regardless of treatment is reported over the 5 d exposure period as expected. Panelists initially preferred ($P < 0.05$) needle tenderized steaks over brine injected steaks, however starting at d 3 and continuing to the end of the evaluation (d 5), brine injected steaks were preferred ($P < 0.05$) over needle tenderized steaks (Figure 6). Also, there was an interaction of treatment x grade reporting select grade roasts having higher ($P<0.05$) subjective color ratings than choice grade roasts within the brine injection treatment (4.58 vs 3.72) compared to the needle tenderized treatment (3.62 vs 3.59).

Summary

Moisture enhancement increased water retention in the treated beef steaks while having positive affects on all sensory attributes and tenderness. Although the moisture enhancement treatment decreased objective retail color values, the treatment decreased the rate of color degradation over time suggesting color stability in the retail case. Neither initial tenderness nor grade had an effect on sensory attributes.

Implications

Boleman et. al, (1997) suggests that consumers are willing to pay for a guaranteed more tender beef product. Moisture enhancement may promote beef products of lower grades and tougher muscles by meeting the demands of consumers. Utilizing more of the carcass may create a significant economic impact on the beef industry. Also, this enhancement method may decrease producer selection pressures. By meeting the desired palatability characteristics, moisture enhancement may be a way to increase loyalty and confidence among consumers.

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Tables and Graphs

Table 1. Comparison of chemical composition, Warner-Bratzler Shear Force, cooking loss and drip loss between treatment and grade for *gluteus medius*.

	Treatment[a]			Grade[b]		
	BI	NT	StdErr	SE	CH	StdErr
WBS, kg	2.66*	3.54*	0.07	3.14	3.06	0.07
% Cooking Loss	19.87*	23.95*	0.51	21.49	22.33	0.52
% Driploss	0.94*	2.42*	0.11	1.75	1.90	0.11
pH	5.85*	5.66*	0.02	5.75	5.75	0.02
% Moisture	71.07*	72.79*	0.41	71.69	72.17	0.40
% Protein	67.54*	80.04*	0.92	74.83*	72.75*	0.92
% Fat	10.90	12.17	0.73	10.02*	13.05*	0.73
% Ash	10.07*	3.79*	0.26	6.98	6.89	0.26

[a] Treatment = Brine Injected (**BI**) and Needle Tenderized (**NT**)
[b] Grade = Select (**SE**) and Choice (**CH**)
* Values differ significantly ($P < 0.05$)

Table 2. Comparison of initial tenderness in tender and tough roasts (days 3, 14 and 21) between brine injected, needle tenderized and control treatments for *gluteus medius*.

	BI[a]		NT[b]		C[c]	
	WBS, kg	StdErr	WBS, kg	StdErr	WBS, kg	StdErr
Tender						
Day 3	3.87	0.07	3.87	0.07	3.87	0.07
Day 14	2.67^{x}	0.08	3.49^{y}	0.08	3.79^{z}	0.08
Day 21	2.52^{x}	0.09	3.47^{y}	0.09	3.44^{y}	0.08
Tough						
Day 3	3.78	0.09	3.78	0.09	3.78	0.09
Day 14	2.61^{x}	0.11	3.46^{yz}	0.11	3.53^{z}	0.11
Day 21	2.57^{x}	0.12	3.53^{z}	0.12	3.27^{y}	0.11

[a] **BI** = Brine Injected
[b] **NT** = Needle Tenderized
[c] **C** = Control
[xyz] Values with different superscripts differ ($P < 0.05$)

Table 3. Comparison of initial tenderness, sustained tenderness, initial juiciness, sustained juiciness, beef flavor and overall acceptability between treatments in the trained sensory panel for *gluteus medius*.

	BI[a]	NT[b]	StdErr
Initial Tenderness	6.94*	5.85*	0.24
Sustained Tenderness	6.75*	5.48*	0.28
Initial Juiciness	7.15*	6.10*	0.19
Sustained Juiciness	6.80*	5.15*	0.24
Beef Flavor	6.78*	5.86*	0.17
Overall Acceptability	6.88*	5.40*	0.24

[a] **BI** = Brine Injected
[b] **NT** = Needle Tenderized
* Values differ significantly ($P < 0.05$)

Table 4. Comparison of objective color between brine injected and needle tenderized treatments for *gluteus medius*.

	BI[a]	NT[b]	StdErr
Minolta L*	41.54*	44.05*	0.29
Minolta a*	6.10*	9.02*	0.20
Minolta b*	6.20*	7.85*	0.15

[a] **BI** = Brine Injected
[b] **NT** = Needle Tenderized
* Values differ significantly ($P < 0.05$)

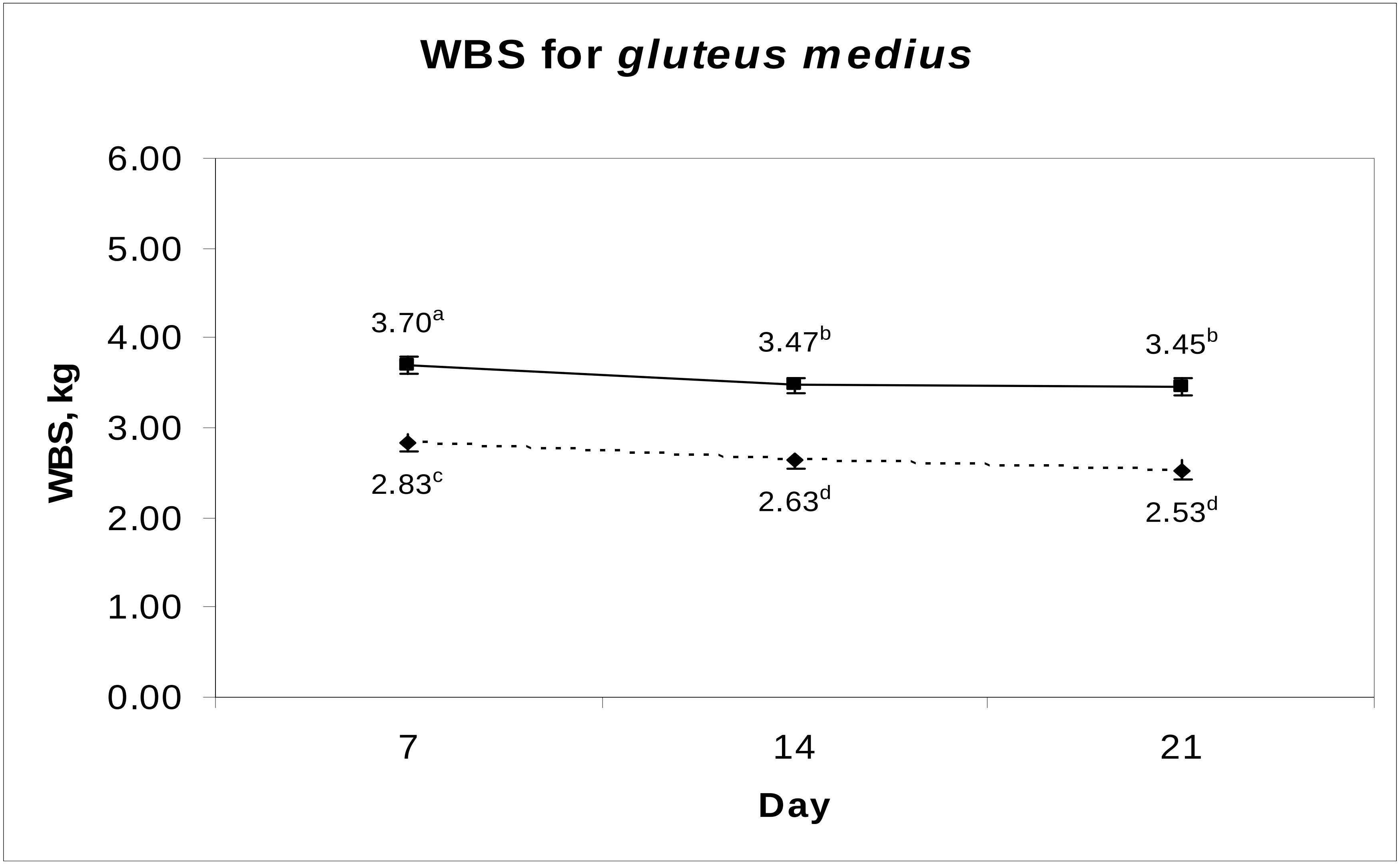
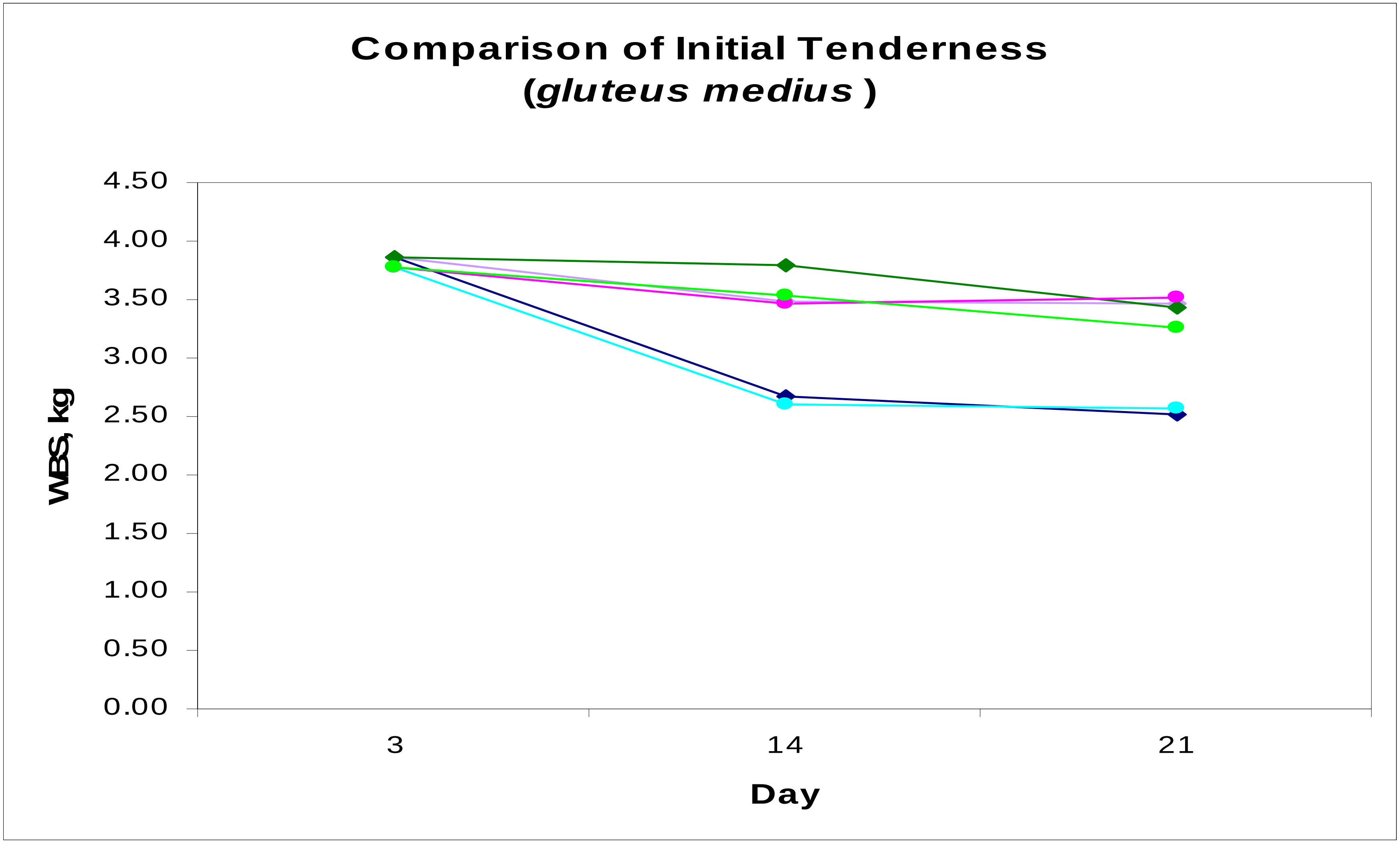


Figure 1. Comparison of Warner-Bratzler Shear Force (days 7, 14 and 21) between brine injected (-◆---◆---◆-) and needle tenderized (─■─■─■─) treatments for *gluteus medius*. Values bearing different superscripts differ ($P < 0.05$).



Legend: Tender BI Tender NT Tender C Tough BI Tough NT Tough C

Figure 2. Comparison of initial tenderness in tender and tough roasts (day 3, 14, and 21) between brine injected (BI), needle tenderized (NT) and control (C) treatments for *gluteus medius.*

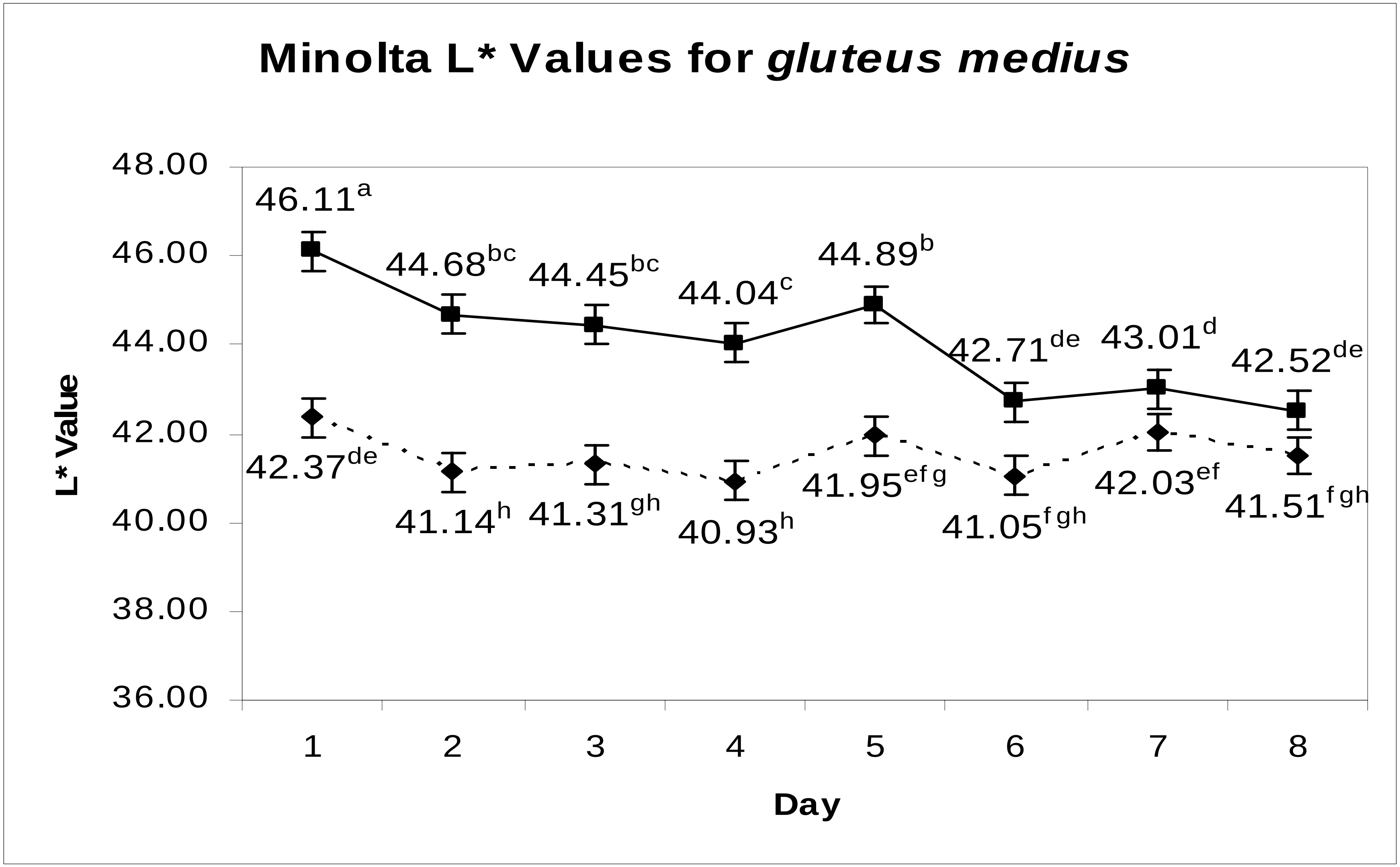


Figure 3. Comparison of Minolta L* values between brine injected (- ◆ - - ◆ - - ◆ -) and needle tenderized (—■—■—■—) treatments for *gluteus medius*. Values bearing different superscripts differ ($P < 0.05$).

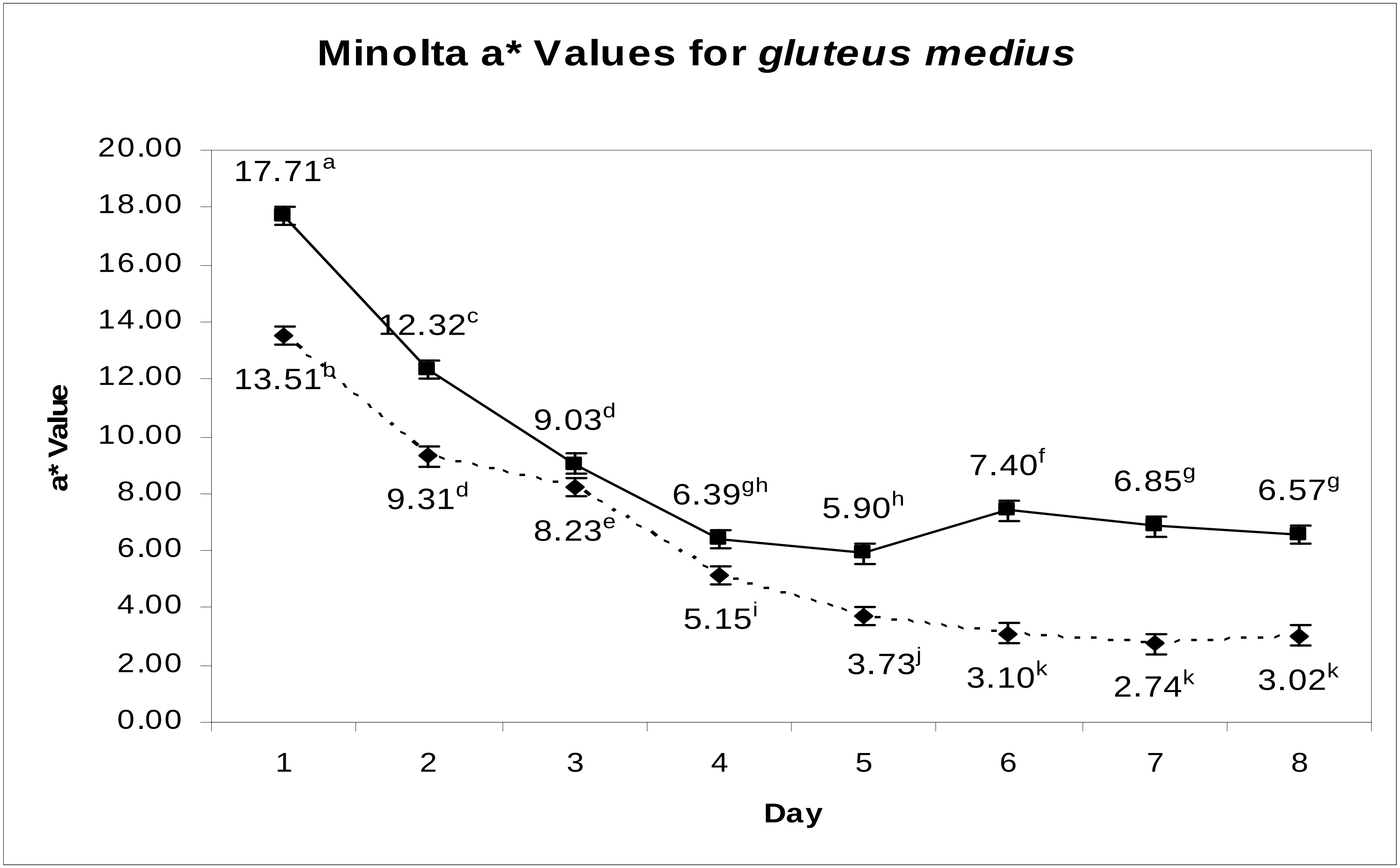


Figure 4. Comparison of Minolta a* values between brine injected (- -◆- - -◆- - -◆- -) and needle tenderized (—■—■—■—) treatments for *gluteus medius*. Values bearing different superscripts differ ($P < 0.05$).

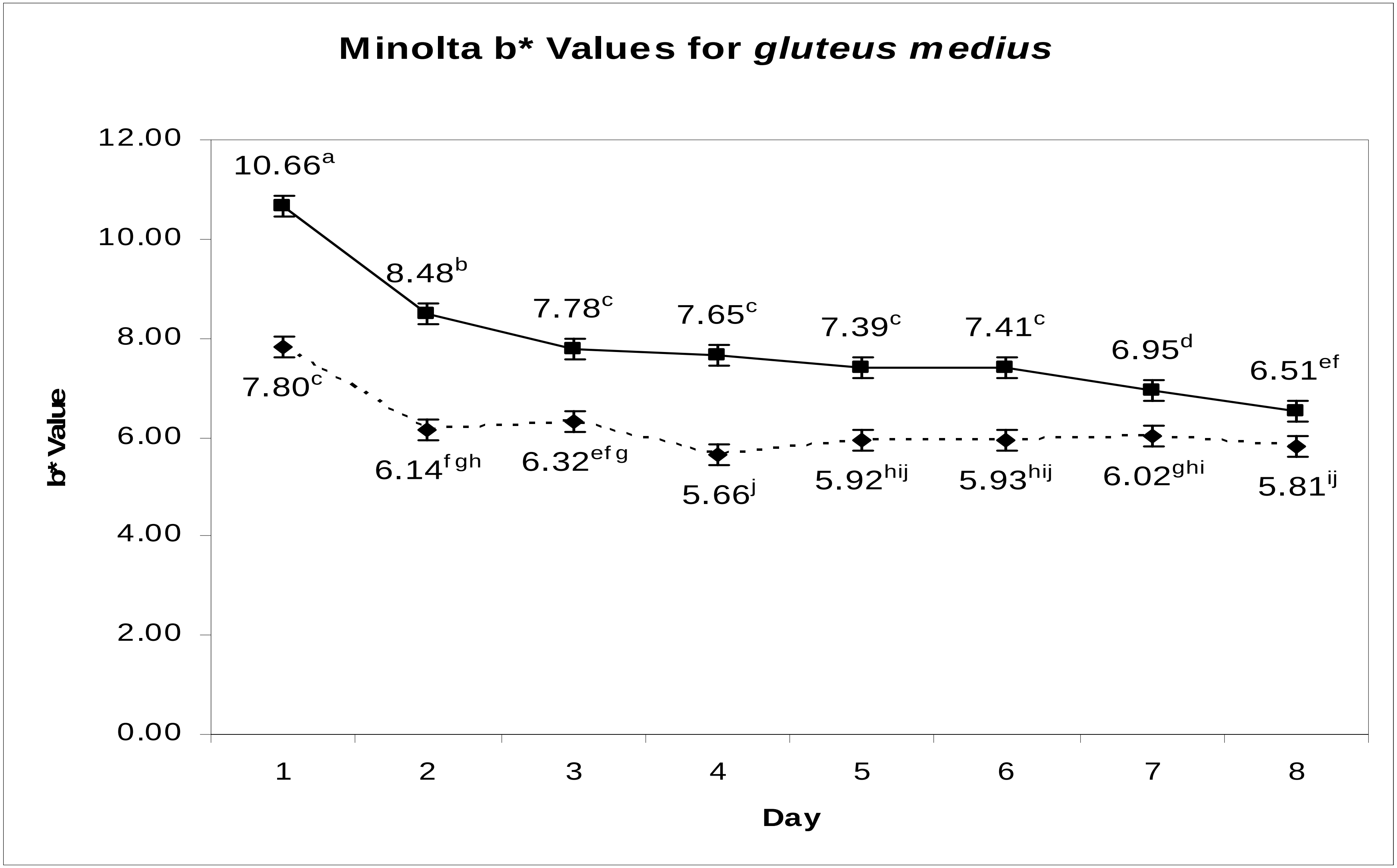


Figure 5. Comparison of Minolta b* values between brine injected (-◆--◆--◆-) and needle tenderized (—■—■—■—) treatments for *gluteus medius*. Values bearing different superscripts differ ($P < 0.05$).

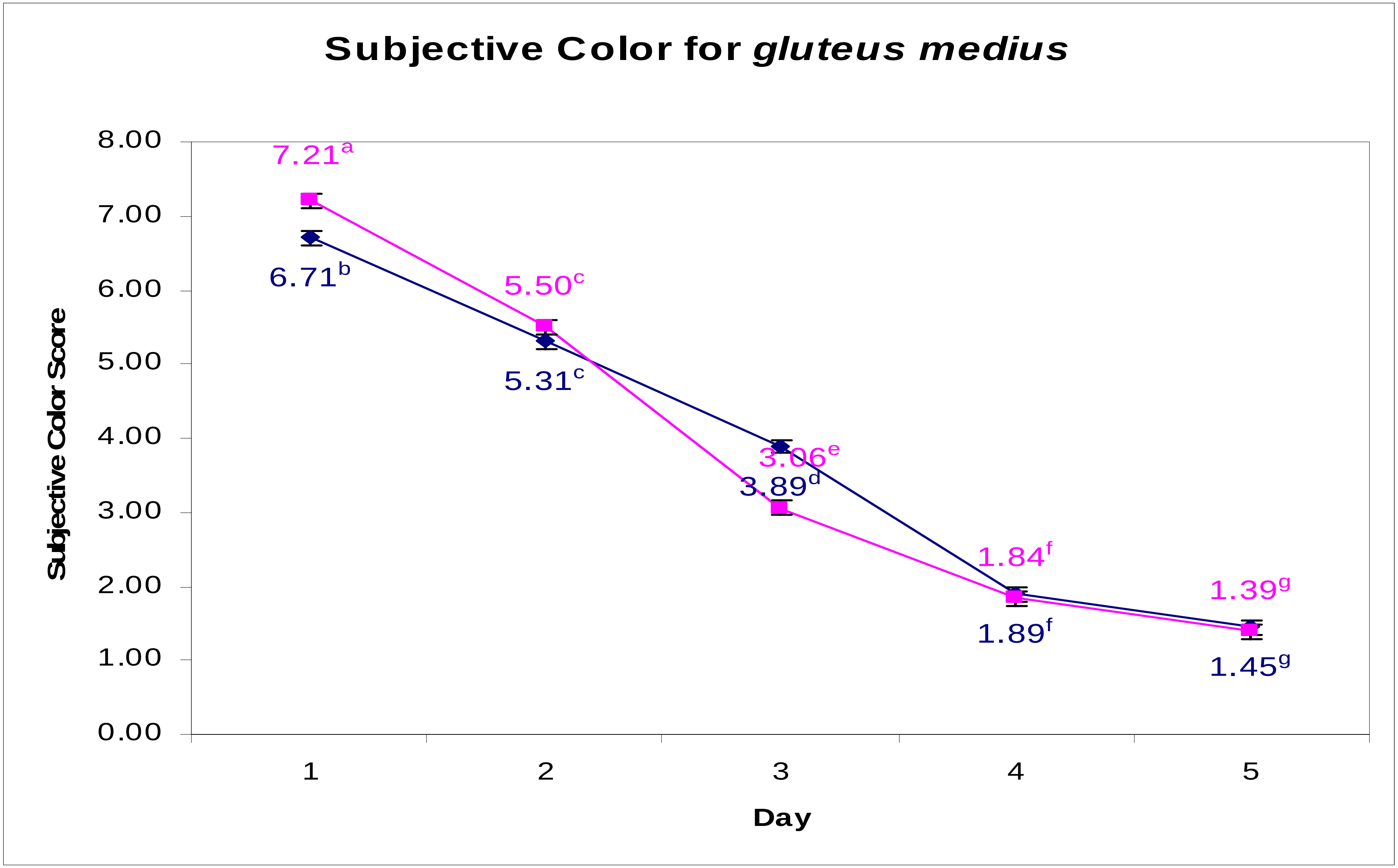


Figure 6. Comparison of subjective color between brine injected (—◆—◆—◆—) and needle tenderized (—■—■—■—) treatments for *gluteus medius*. Values bearing different superscripts differ ($P < 0.05$).